PUBLICATIONS.

The Penokee Iron-Bearing Series of Michigan and Wisconsin. By R. D. IRVING and C. R. VAN HISE. Monograph U. S. Geological Survey No. XIX., 1892. Quarto, 534 pp.; with 37 plates representing microscopic sections of the rocks of the district, and geological sections and maps of the region.

The region discussed in this volume lies a few miles south of Lake Superior, partly in Michigan, partly in Wisconsin. It extends from Lake Gogebic in Michigan westward in a narrow strip from one to three miles wide, to Lake Numakagon in Wisconsin, a distance of about eighty miles. This area is covered by rocks of the Penokee series, which dip northward in a long and very regular monocline. The series is underlain by crystalline rocks designated the Southern Complex, though occasionally there intervenes between this and the Penokee series a formation designated the Cherty limestone. The Penokee series is overlain by the Keweenaw series, which in turn is overlain by the Eastern Sandstone.

The Southern Complex is considered to be of Archean age and is discussed more fully in another part of this review by Professor Iddings. It was much eroded and reduced almost to base level before the deposition of the overlying formations.

The cherty limestone is considered to belong to the Lower Huronian division of the Algonkian. It is composed of cherty, dolomitic limestone alternating with layers of chert, and averages about 300 feet in thickness. It is not continuous throughout the region, but is found intermittently between the Southern Complex and the Penokee series. A period of erosion of this formation occurred before the deposition of the overlying series, but it was of far less magnitude than the preceding period of erosion of the Southern Complex.

The Penokee series is considered to be the equivalent of the Animikie, and belongs to the Upper Huronian division of the Algon-

kian. It is composed of three members designated in an ascending order as the Quartz-Slate member, the Iron-bearing member, and the Upper-Slate member. All of these lie conformably with each other, but differ considerably in the character and the mode of deposition of their constituents. The Quartz-Slate and Upper-Slate members are of clastic origin, while the Iron-bearing member is largely composed of chemically deposited materials.

The Quartz-Slate member is about 500 feet thick, is composed of fragmental materials among which quartz predominates, and is capped by a layer of pure quartzite, which has played an important part in the formation of the iron ore bodies. The Iron-bearing member averages about 800 feet in thickness, and is composed of cherty iron carbonates, ferruginous slates and cherts, and actinolitic and magnetitic slates. The cherty iron carbonates are the original form from which the other rocks mentioned were derived. The iron ore deposits of the region were also formed from the same sources and in a manner to be discussed more fully below. The Upper-Slate member averages about 12,000 feet in thickness. It is of clastic origin, and composed mostly of graywackes or graywacke-slate, though sometimes altered to a crystalline schist.

Numerous bodies of diabase have been intruded into the Penokee series, both in the form of dikes and of interbedded sheets probably contemporaneous with the dikes, both being presumably of Keweenawan age. These diabase intrusions have had a most important effect on the formation of the iron ore deposits, as will be noticed later on.

The Penokee series was subjected to a period of considerable erosion before the depositions of the overlying Keweenaw series, and this in turn was again subjected to disturbance and erosion before the deposition of the overlying Eastern Sandstone. It will thus be seen that the Penokee series is separated by marked unconformities, both from the underlying Southern Complex on the south and the overlying Keweenaw series on the north; while it is terminated on the east by the Eastern Sandstone and is abruptly cut off on the west by erosion. It occupies, therefore, an isolated area, unique among rocks of this age for the clear definition of its members and the simplicity of its structure.

The iron deposits which have made the Penokee region (also known as Penokee-Gogebic region) celebrated as a mining district, occur in the lower horizon of the Iron-bearing member of the Penokee series, and generally immediately over the quartzite which forms the uppermost horizon of the Quartz-Slate member. The diabase dikes which

occur in the Penokee series came up partly, at least, before the enclosing rocks assumed their present position, and they have since been subjected to the same disturbance which developed the monoclinal structrue of the region. The result is that in places where the dikes intersected the quartzite of the Quartz-Slate series V-shaped troughs have been formed, opening upwards and bordered on one side by diabase and on the other by quartzite. In these troughs, of course, were originally included V-shaped masses of the cherty iron carbonates of the Iron-bearing member which immediately overlies the quartzite. This material contained too little iron to be of commercial value, but by a process of chemical concentration in the V-shaped troughs, rich bodies of pure hematite have been formed. It is shown that during the process of erosion and superficial oxidation one side of the V-shaped mass of cherty iron carbonates was oxidized more rapidly than the other, so that the iron in it was converted to sesquioxide, while the iron in the other side was still in the form of carbonate. Surface waters percolating through the oxidized part of the V-shaped mass, therefore, continued down without losing much of their oxygen, for the materials which they met in their course had already been oxidized. These waters in descending met one of the sides of the V-shaped trough and were deflected down to where the two sides met, with considerable oxygen still in solution. Surface waters, however, percolating through the less thoroughly oxidized part of the V-shaped mass lost their oxygen in oxidizing carbonate of iron in the unoxidized cherty iron carbonates, but in turn they received carbonic acid from the decomposed carbonate. This enabled them to dissolve some of the iron carbonate not yet decomposed; and thus ladened with iron in solution, they percolated down, and were deflected by the other side of the trough into its lower part. Here they met the waters containing oxygen which at once oxidized the iron held in solution and precipitated it in a sesquioxide condition. In this way the large bodies of iron ore were collected; and by the same waters that brought the iron into the trough the silica in the cherty material was removed, thus leaving a pure iron ore. It is evident that during the erosion of the cherty iron carbonates the iron from them would be gradually leached out and carried into the trough, instead of lost in surface waters.

The evidence that such a process has gone on is very strong and has been presented in a most admirable manner by Professor Van Hise, whose work shows very clearly the fallaciousness of the old idea that the

iron deposits were simply layers interbedded with the associated rocks. The same theory of the formation of iron deposits, changed a little to suit local details, might consistently be applied to many iron deposits in the eastern states and in the Rocky Mountains, though of course the trough in which concentration occurred need not necessarily have been formed by a dike and a quartzite, as in the Penokee region. The trough may be formed in a great number of ways, by disturbances and foldings in the rocks without any dikes, by the crumbling of local areas of rock, etc.

In addition to the purely geological part of the volume, a chapter on previous geological work in the district and a full summary of the literature is given. A most excellent feature of the volume is the system of clear, brief summaries at the end of each chapter and the general outline of the volume given in the beginning, both of which are of the greatest value in giving a correct understanding of the subject, as well as a convenient means of rapid reference.

R. A. F. PENROSE, JR.

The Petrology of the Penokee Iron-Bearing Series.

As an example of the value of petrographical study, both of the rocks of a metamorphosed series, *per se*, and of the production of a metalliferous deposit of great economic importance, the monograph by Irving and Van Hise stands preëminent. Not only has the investigation been thoroughly and skillfully made, but the data obtained have been presented in such a manner as to render them accessible to those who may wish to follow the investigation step by step, and be able to form, as it were, an independent opinion. At the same time the results are stated in a concise form with sufficient explanation for those who do not care to follow the study in detail. This has been accomplished by placing the results in the form of general statements, and by supplementing them with a tabulation of the observations. In the case of each formation studied the field occurrence and megascopical structure have been combined with the microscopical characteristics in shaping the history of the formation. And the probable origin of each has been reasonably demonstrated.

Owing to the fullness of the petrographical portions of the report, which, in fact, constitute the foundation of the work, it will not be possible to do justice to it in a brief review, in which only a few of the salient features can be pointed out. The most notable of these are in

connection with the terrane of crystalline schists underlying the Penokee series, and known as the Southern Complex. The first is the diverse petrographical character of these rocks and their probable igneous origin. The second is the author's use of the term granite. These will appear from the following digest:

The Southern Complex is considered to be Archean, and is designated on the map as granite, granitoid-gneiss, schist and fine-grained gneiss. In the text these rocks are said to be exceedingly complex both as to their lithological character and structural relations, comprising unmistakable eruptives, including diabases (considered post-Archean in age), syenites, gneissoid-granites, granites, and many different varieties of gneisses and schists. The areas of granite and schist alternate with one another, and are associated in such a manner as to indicate that the latter are metamorphosed forms of the granites. Instances of the alteration of feldspar to quartz and biotite are described, and the changing of a feldspar-rock into a mica-schist. The "Western granite" area consists of "granite and gneissoid granite," the latter varying in structure from almost granitic to "extremely contorted and quite finely foliated." The mineral composition is nearly constant throughout this area and is that of granite. The "Western green schists" are distinct from the rocks just noted. In different parts of the area they have very different characters. Most of them are finely schistose gneisses of various kinds, some appear to be highly altered basic eruptives. The "Central granite" has a large area and is both granitic and gneissoid. "The rocks here included vary greatly in their chemical composition, running from granites to gabbros. The three chief types of rocks are the granites, the syenites, and the gabbros." Concerning the "Eastern granite" the author says: "The phase here included run from typical syenites to typical quartzose granite."

The diabases occurring in the Southern Complex are considered to be contemporaneous and in some cases continuous with those forming dikes in the Penokee series.

The author states that "the kinds of rocks mentioned in the Southern Complex are not necessarily all which may there exist," since only a fraction of the exposures were visited. The most important fact developed by the study of this complex is the apparent gradual change between the massive rocks and the schistose ones, and the conclusion that the latter are metamorphosed eruptive rocks.

It is evident that in the region described the Archean formation consists of rocks of widely different composition, and that the variations are frequently repeated throughout the area.

The use of the term granite in a general sense for granular rocks, without regard to their composition, must naturally preclude its use in the narrower petrographical sense. The need of some widely applicable terms to designate groups of rocks resembling one another in outward, megascopical appearance is becoming more and more urgent as the refinements of advanced petrography tend to discriminate more closely upon a basis of characters not distinguishable in the outward appearance of rocks. The necessity of maintaining terms which may be applied to rocks by those not conversant with petrographical methods of investigation, or which may be used until the precise character of the rock has been discovered, must be evident to all geologists. The same term, however, should not be used in a general and in a restricted sense. As others have pointed out, *granite* may properly be employed as a general term for all phanerocrystalline, evenly granular rocks. A new term would be required for such rocks, when composed of quartz, alkali-feldspars with or without ferro-magnesian silicates.

The petrographical study of the members of the Penokee series has led to the conclusion that the chert and limestone of the cherty limestone member are water-deposited sediments, whose origin is not improbably organic, the silica having been rearranged and the limestone dolomitized. The study of the quartz-slate member shows its composition to be varied; that it is always fragmental, and that its induration is due to the secondary enlargement of quartz fragments, rarely of feldspar fragments. It is also due to the alteration of the feldspar to biotite, chlorite and quartz by the accession of material from neighboring sources. The source of the original fragments composing this formation was chiefly the Southern Complex.

The petrographical study of the Iron-bearing member has demonstrated satisfactorily the origin and mode of formation of the ore-bodies, the substance of which is reviewed more particularly by Professor Penrose.

The upper slate member was found to be of fragmental origin, and was derived from the Southern Complex. Metasomatic changes have altered the original deposits to a greater or less extent; the extreme metamorphism resulting in rocks in no way distinguishable from crystalline schists. This change has been most complete in nearly pure

arkoses which have been converted into mica-schists. The change of feldspars into biotite and quartz is notable.

The eruptive rocks cutting the Penokee series in the form of dikes and sheets are normal diabases, occasionally grading into gabbro. The chief feature of interest developed in their study is the fact that their freshness and alteration is closely dependent on the permeability of the adjacent rocks to percolating waters, showing that environment may be a more important element than age in the preservation of a rock.

The formations composing the Eastern area of the Penokee series have been modified by contemporaneous volcanic action, and the accumulation of surficial lavas, both massive and fragmental. These were of a basic character, some being porphyrites, others diabases, grading into gabbros that are considered to be deep-seated parts of the lavas. These rocks have been altered into greenstones. The other rocks of the Eastern area resemble those of the Western area in petrographical characters.

In the closing chapter of the monograph the flexures and faults are discussed, and the structure of the region is described. The Penokee series is correlated with the Animikie series, and also with the Marquette. Other correlations are suggested.

JOSEPH P. IDDINGS.

Summary of Current pre-Cambrian North American Literature.[1]

Cross[2] describes intrusive sandstone dikes in the Pike's Peak granite. The material has all the characteristics of dikes. The larger number are a few inches or a few feet thick, but they vary from a film to those three hundred yards wide. Some of the larger have been followed for nearly a mile. The dykes have a general trend parallel to the belt in which they occur, and they are connected in an intricate way by diagonal fissures, and all are regarded as belonging to a single fissure system. The material of the dikes is fine and even-grained sand grains, either in the form of sandstone or more commonly indurated to a dense hard quartzite. The induration is mainly due to limonite, but in some degree is due to muscovite, and to secondary silica. The

[1] Continued from p. 454, Vol. II. JOURNAL GEOLOGY.

[2] Intrusive Sandstone Dikes in Granite, by WHITMAN CROSS. Bull. Geol. Soc. Am., Vol. 5, pp. 225–230, pl. 8, 1894.